

Hydraulics

3rd Year civil

First Term (2009 - 2010)

Chapter (   )

2009 - 2010

بسم الله الرحمن الرحيم

Specific Force

القوه التى تسبب حركه السريان من قطاع لآخر داخل المجرى المائى هى القوه التى تنتج من التغير فى كميه الحركه بين القطاعين

$$Momentum = \rho . Q . V$$

بالإضافه إلى وجود القوه الناتجه من ضغط السائل داخل المجرى المائى وعليه

تكون القوه الكليه الموجوده فى المجرى المائى هى مجموع هاتين القوتين

$$F_{total} = Momentum + Pressure$$

$$= \rho . Q . V + \frac{1}{2} \gamma . y^2$$

وتعرف هذه القوه بالقوه النوعيه specific force

Specific Force:

it is the sum of hydrostatic force and momentum in section

Specific Force diagram:

هو العلاقة بين القوه النوعية (F) والعمق (Y)
عند ثبات التصرف (Q)

y
y_1
y_c
y_2
Q = Const.
Fn<1
Fn=1
Fn>1
Fmin
F
F

Critical water depth (y_c)

هو العمق الذى تكون عنده قيمة القوه النوعية داخل المجرى المائى اقل ما يمكن عند ثبات التصرف

Conjegate depths: الأعماق المترافقة

هما العمقان اللذان لهما نفس القوه النوعية داخل القطاع عند ثبات التصرف ويكون أحدهما super-critical والآخر sub-critical ويحدثان معاً .

For Rectangular section:

$$\because F = \frac{\gamma \cdot y^2}{2} + \rho \cdot Q \cdot v$$

for unit width

$$F = \frac{\gamma \cdot y^2}{2} + \rho \cdot q \cdot v$$

$$\therefore F = \frac{y^2}{2} + \frac{\rho}{\gamma} \cdot q \cdot v \quad \Rightarrow \quad \frac{\rho}{\gamma} = \frac{1}{g}$$

$$\therefore F = \frac{y^2}{2} + \frac{q \cdot v}{g} \quad \Rightarrow \quad q = v * y$$

$$F = \frac{y^2}{2} + \frac{q^2}{g \cdot y}$$

for Fmin $\frac{dF}{dy} = 0$

$$0 = \frac{2y}{2} - \frac{q^2}{g y^2}$$

$$\frac{q^2}{g y^2} = y \quad \Rightarrow \quad \frac{q^2}{g} = y^3$$

$$y_c = \sqrt[3]{q^2/g} \quad \text{(Critical depth)}$$

$$F_{min} = \frac{y^2}{2} + \frac{y^3}{y} = 1.5 y_c^2$$

For non rectangular section:

$\because dA = T \times dy$

$$\frac{dA}{dy} = T$$

T

dy

$$\because \quad F = \frac{\gamma \cdot y^2}{2} + \frac{\gamma}{g} Q \cdot V$$

$$F = \frac{y^2}{2} + \frac{Q \cdot V}{g}$$

$\because Q = A * V$,

$$\therefore \quad F = \frac{y^2}{2} + \frac{Q^2}{g \cdot A}$$

$\epsilon = y + \frac{v^2}{2g}$

$\frac{d\epsilon}{dy} =$

for F_{min} $\quad \frac{dF}{dy} = 0$

$$0 = y - \frac{Q^2}{gA^2} \frac{dA}{dy}$$

$$y = \frac{Q^2 \cdot T}{g \cdot A^2}$$

$$\boxed{\frac{Q^2}{g} = \frac{y \cdot A^2}{T}}$$

$$\boxed{F_{min} = \frac{y_c^2}{2} + y_c \cdot y_h}$$

application ..

Hydraulic Jumb

القفزه الهيدروليكيه

* Defination ..

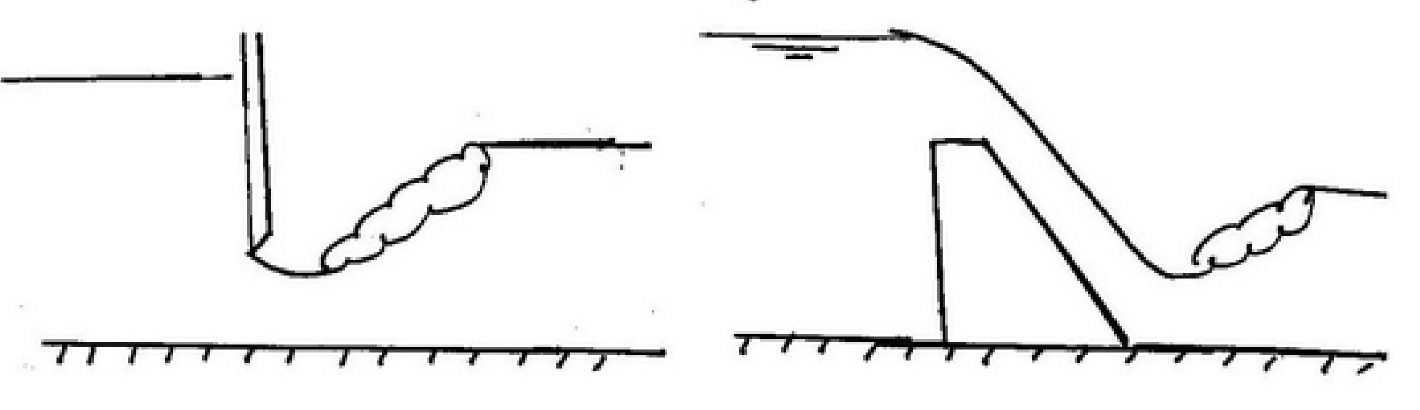
هى ظاهره تحدث داخل المجرى المائى نتيجه انتقال .
السريان من حاله super critical الى حالة sub. critical

* Importance :

ترجع أهميه القفزه الهيدروليكيه إلى انها وسيله جيده جداً فى تشتيت الطاقه الزائده داخل المجرى المائى .

* Location :

1- down stream weirs
2- down stream gates

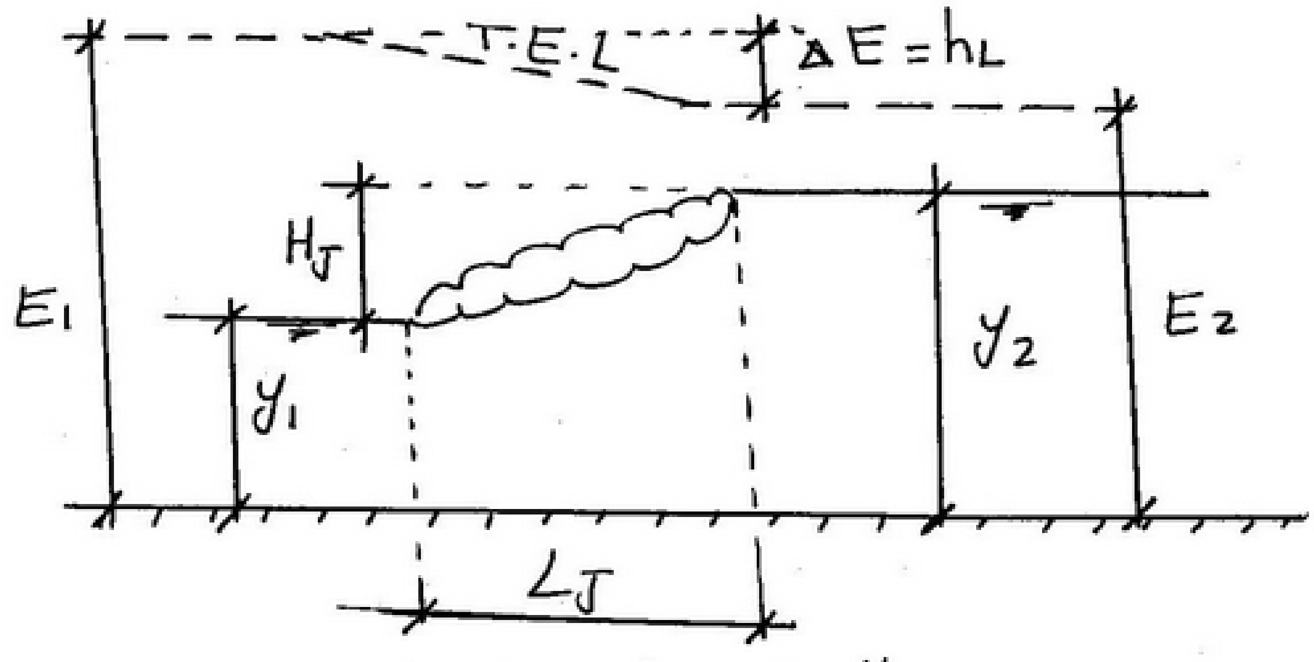


Classification of Hydraulic Jumb:

يعتمد تصنيف القفزه الهيدروليكيه على قيمه (Fn) في بدايه القفزه

Fn = 1 → 1.7	undular jumb
Fn = 1.7 → 2.5	weak "
Fn = 2.5 → 4.5	oscillating
Fn = 4.5 → 9.0	steady jumb
Fn > 9.0	strong jumb

Hydraulic Jumb element:



y_1 : initial water depth.

y_2 : sequent water depth.

L_J : Jumb length

H_J : Jumb height.

E_1 : initial energy.

E_2 : sequent energy.

$\Delta E = h_L$: head loss
energy loss

Relative relations:

العلاقات النسبيه هى العلاقه بين العناصر المختلفه للقفزه الهيدروليكيه والطاقه الإبتدائيه (E_1)

y_1/E_1 : relative initial depth

y_2/E_1 : " sequent "

L_J/E_1 : " jumb length

H_J/E_1 : " " height.

$\Delta E/E_1$: " energy Loss

E_2/E_1 : efficiency of Jumb (η)

Analysis of Hydraulic Jumb:

For Rectangular section:

- $y_c^3 = \frac{q^2}{g} = 0.5\,(y_1 y_2)(y_1 + y_2)$

- $\frac{y_1}{y_2} = 0.5\left[\sqrt{1 + 8(F_r)_2^2} - 1\right]$

- $L_J = 5.2\, y_2$ oR $L_J = 5 \rightarrow 6\ H_J$
- $H_J = y_2 - y_1$
- $h_L = E_1 - E_2 = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$
- $\eta = \frac{E_2}{E_1}$

In non Rectangular section

يتم تطبيق معادلة الـ Momentum بين القطاعين

$$P_1 + M_1 = P_2 + M_2$$

$$\gamma \cdot h'_1 \cdot A_1 + \frac{\gamma Q^2}{g A_1} = \gamma \cdot h'_2 \cdot A_2 + \frac{\gamma Q^2}{g \cdot A_2}$$

h' : هي المسافة بين مركز ثقل الشكل و سطح السريان

Specific Force

1- In a stream flowing at the rate of 100 c.f.s, can a hydraulic jump with an initial depth of 3.0 ft take place in any of the following channel :
   a- a rectangular channel of bed width 3.0ft
   b- a trapezoidal channel of bed width of 2.0 ft and 1:1 side slope
   c- a channel of parabolic section whose formula is $X^2=4Y$

   How much would be conjugate depth and head loss in jump if any is formed.

2- A triangular channel whose top width is three times the depth , (n=0.025) passes a discharge of 100 c.f.s find the critical depth and critical slope. If this discharge paths at a depth of 1.0 ft, find the sequent depth if a hydraulic jump is formed, what would be the energy lost through the jump and the efficiency of the formed jump.

3- A trapezoidal channel of bed width 10.0 m and side slopes of 1 : 1 , conveying a discharge of 100 m3/sec. The water depth is 1.50 m determined.
   a- can a hydraulic jump tale place
   b- the sequent depth.
   c- The loss in kinetic energy
   d- The energy dissipated in H.P

4- A hydraulic jump occurs in a horizontal storm sewer of square cross section of side 2.0 m, before the jump the water depth is 0.5 m and just downstream the jump the sewer is full with a gauge pressure of 0.3 kg/cm^2 at the top predict the flow rate.

5- A hydraulic jump is formed in a horizontal open channel of trapezoidal section , the bed width is 10.0 m and side slopes 2:1, the two conjugate depths are 2.0m , and 5.0m, calculate the discharge passing through the canal , the relative loss, the power dissipated by the jump, the relative sequent depth. The jump length, and the efficiency of the jump.

6- Water flows below a sluice gate in a rectangular channel 6.0 m width and forms a hydraulic jump whose conjugate depths are 1.50 m, and 3.0 m. find the rate of flow, and the depth upstream the gate assuming no losses to occur between the upstream side and beginning of the jump.

7- In a rectangular horizontal channel a discharge of 10.0 m3/sec/m` passed at a depth of 1.0 m fid the depth downstream of the hydraulic jump when it forms. If an obstruction is placed on the bed across the channel, in the jump zone, to reduce the downstream depth to 3.40 m find the force exerted upon the obstruction per meter width.

بسم الله الرحمن الرحيم

Q (1):

Given:

$Q = 100\ ft^3/sec.$

Req.: * Can a H.J take place

$y_1 = 3.0\ ft.$

a - Rectangular $b = 3\ ft.$

b - Trapizoidal $b = 2\ ft$ $Z = 1:1$

c - parabolic sec. $x^2 = 4y$

* $y_2 = ?$, $\Delta E = ?$

اذا حدث تكون قفزه هيدروليكيه.

Sol.:

(a):

$$F_1 = \frac{V_1}{\sqrt{g \cdot y_1}}$$

$y_1 = 3.0\ ft$

$b = 3\ ft$

$$V_1 = \frac{Q}{A_1} = \frac{100}{3 \times 3} = 11.11 \text{ ft/s}$$

$$F_1 = \frac{11.11}{\sqrt{32.2 \times 3}} = 1.13 > 1$$

هناك احتمال حدوث قفزه هيدروليكيه

$$\frac{y_1}{y_2} = 0.5\left[\sqrt{1 + 8F_2^2} - 1\right]$$

$$\frac{y_2}{y_1} = 0.5\left[\sqrt{1 + 8F_1^2} - 1\right]$$

$$\frac{y_2}{3} = 0.5\left[\sqrt{1 + 8 \times 1.13^2} - 1\right]$$

$$y_2 = 3.52 \text{ ft} \ \#$$

$$\Delta E = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$ for Rectan. section

$$= \frac{(3.52 - 3)^3}{4 \times 3 \times 3.52}$$

$$\Delta E = 0.0033 \text{ ft} \ \#$$

(b)

$y_1 = 3.0\ ft$, side slope 1:1, $b = 2\ ft$

$$Q = 100\ ft^3/s$$

$$F_n = \frac{V}{\sqrt{g \cdot y_h}}$$

$$y_h = \frac{A}{T}$$

$$A = (b + zy)y = (2 + 1 \times 3) \times 3 = 15\ ft^2$$

$$T = b + 2zy = 2 + 2 \times 1 \times 3 = 8\ ft.$$

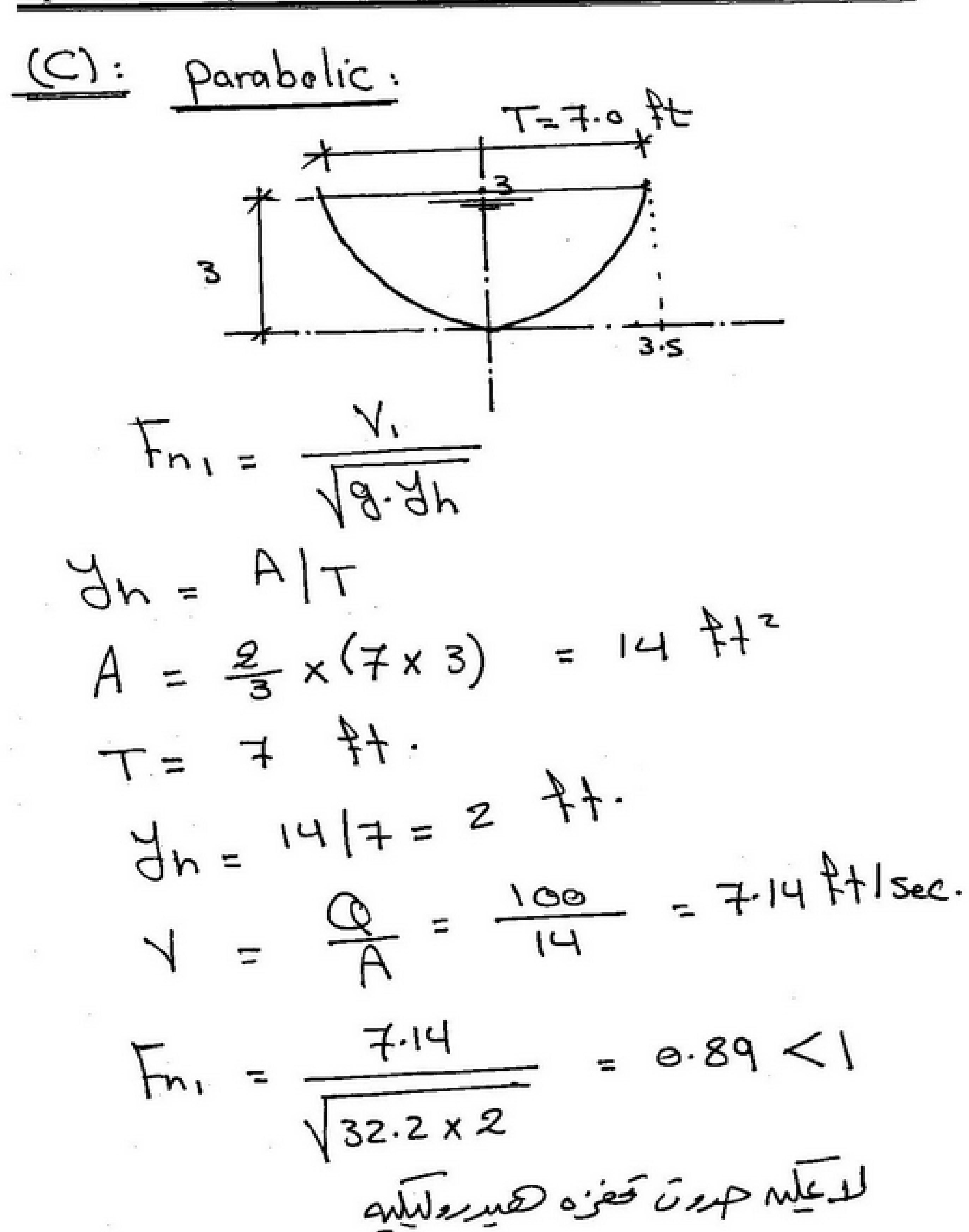
$$y_h = \frac{15}{8} = 1.89\ ft.$$

$$V = \frac{Q}{A} = \frac{100}{15} = 6.70\ ft/sec.$$

$$F_{n_1} = \frac{6.70}{\sqrt{32.2 \times 1.89}}$$

$$F_{n_1} = 0.85 < 1$$

لا عليه حدوث قفزه هيدروليكيه



(C): parabolic:

$$F_{n_1} = \frac{V_1}{\sqrt{g \cdot y_h}}$$

$$y_h = A / T$$

$$A = \frac{2}{3} \times (7 \times 3) = 14 \ ft^2$$

$$T = 7 \ ft.$$

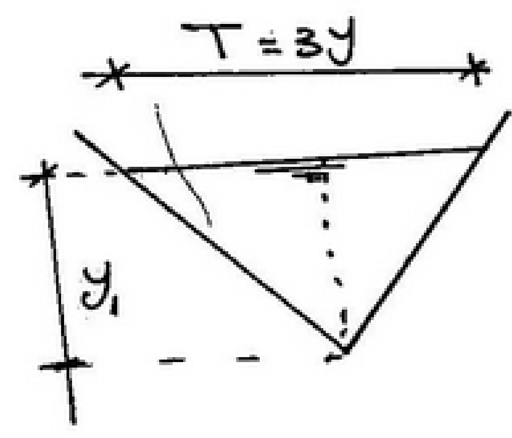
$$y_h = 14/7 = 2 \ ft.$$

$$V = \frac{Q}{A} = \frac{100}{14} = 7.14 \ ft/sec.$$

$$F_{n_1} = \frac{7.14}{\sqrt{32.2 \times 2}} = 0.89 < 1$$

لا عليه حدوث قفزه هيدروليكيه

Q(2) :



- n = 0.025
- Q = 100 ft³/sec.

Req.: a- y_c = ?? , S_c

b- y_1 = 1 ft. y_2 = ??

- η = ??

Sol.:

$$\because \frac{Q^2}{g} = \frac{A^3}{T}$$

$$T = 3y_c$$

$$A = \frac{1}{2} \times 3y_c \times y_c = 1.5y_c^2$$

$$\frac{(100)^2}{32.2} = \frac{(1.5y_c^2)^3}{3y_c}$$

$$276.05 = \frac{y_c^6}{y_c} = y_c^5$$

$$y_c = 3.10 \text{ ft} \quad \#$$

$$\therefore Q = \frac{1.486}{n} \cdot \frac{A_c^{5/3}}{P_c^{2/3}} \cdot S_c^{1/2}$$

$$A_c = 1.5 \times (3.10)^2 = 14.42 \text{ ft}^2$$

$$P_c = 2\sqrt{(1.5 y_c)^2 + (y_c)^2}$$

$$= 2\sqrt{(1.5 \times 3.1)^2 + (3.1)^2} = 5.60 \text{ ft.}$$

$$100 = \frac{1.486}{0.025} \times \frac{(14.42)^{5/3}}{(5.6)^{2/3}} \times S_c^{1/2}$$

$$S_c = 3.86 \times 10^{-3} \quad \#$$

(b)

$$Fn_1 = \frac{V_1}{\sqrt{g \cdot y_h}}$$

3.0 ft.

$h_i = 0.33$

$y_1 =$ 1.0 ft.

$$A = \frac{1}{2} \times 3 \times 1 = 1.5 \ ft^2$$

$$V_1 = \frac{100}{1.5} = 66.7 \ ft/sec.$$

$$y_h = \frac{1.5}{3} = 0.5$$

$$Fn_1 = \frac{66.7}{\sqrt{32.2 \times 0.5}} = 16.62 > 1$$

يحدث قفزه هيدروليكيه

$$\because \quad P_1 + M_1 = P_2 + M_2$$

$$h_1' \cdot A_1 + \frac{Q^2}{gA_1} = h_2' \cdot A_2 + \frac{Q^2}{gA_2}$$

$$h_1' = 0.33 \ ft.$$

$$A_1 = 1.5 \ ft.$$

$$h_2' = y_2/3 = 0.33 y_2$$

$$A_2 = \frac{1}{2} \times 3y_2 \times y_2 = 1.5 y_2^2$$

$$0.33 * 1.5 + \frac{(100)^2}{32.2 \times 1.5} = 0.33 y_2 * 1.5 y_2^2 + \frac{(100)^2}{32.2 \times (1.5 y_2^2)}$$

$$207.53 = 0.5 y_2^3 + \frac{207.04}{y_2^2}$$

by trial

y_2	6	8	7.5	7.4
R.H.S	113.75	259.2	214.6	206.4

$y_2 \simeq 7.42$ ft. #

$$\because \quad \eta = \frac{E_2}{E_1}$$

$$E_1 = y_1 + \frac{Q^2}{2gA_1^2}$$

$$= 1 + \frac{(100)^2}{2 \times 32.2 \times (1.5)^2} = 70.01 \text{ ft.}$$

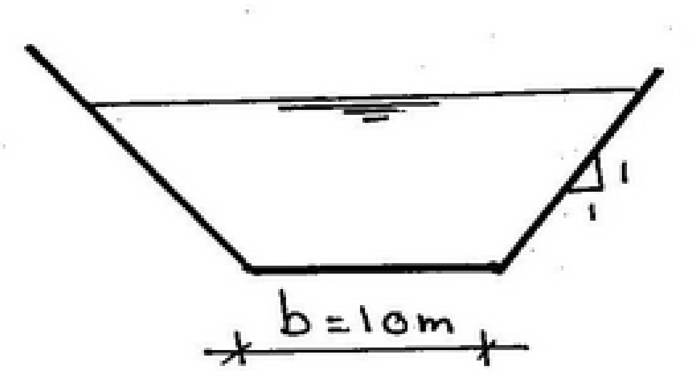
$$E_2 = 7.42 + \frac{(100)^2}{2 \times 32.2 \times 82.58} = 9.3 \text{ ft.}$$

$$\eta = \frac{9.3}{70.01} \times 100 = 13.2\% \quad \#$$

بسم الله الرحمن الرحيم

Q(3):

- $Q = 100\ m^3/s$
- $y = 1.50\,m$



Req.:

- check for H.J
- sequent depth y_2
- Loss in kinetic energy.
- energy dissipated in H.P

Sol.:

$$F_n = \frac{V}{\sqrt{g \cdot y_h}}$$

$$y_h = \frac{A}{T}$$

- $A = (b + zy)y = (10 + 1 \times 1.5) \times 1.5 = 17.25\ m^2$

- $T = b + 2zy = 10 + 2 \times 1 \times 1.5$

  $= 13.0\ m$

- $y_h = \dfrac{17.25}{13.0} = 1.33\ m$

- $V = \dfrac{Q}{A} = \dfrac{100}{17.25} = 5.80\ m/s$

$$F_n = \frac{5.8}{\sqrt{9.81 \times 1.33}} = 1.61 > 1$$

عليه حدوث قفزه هيدروليكيه

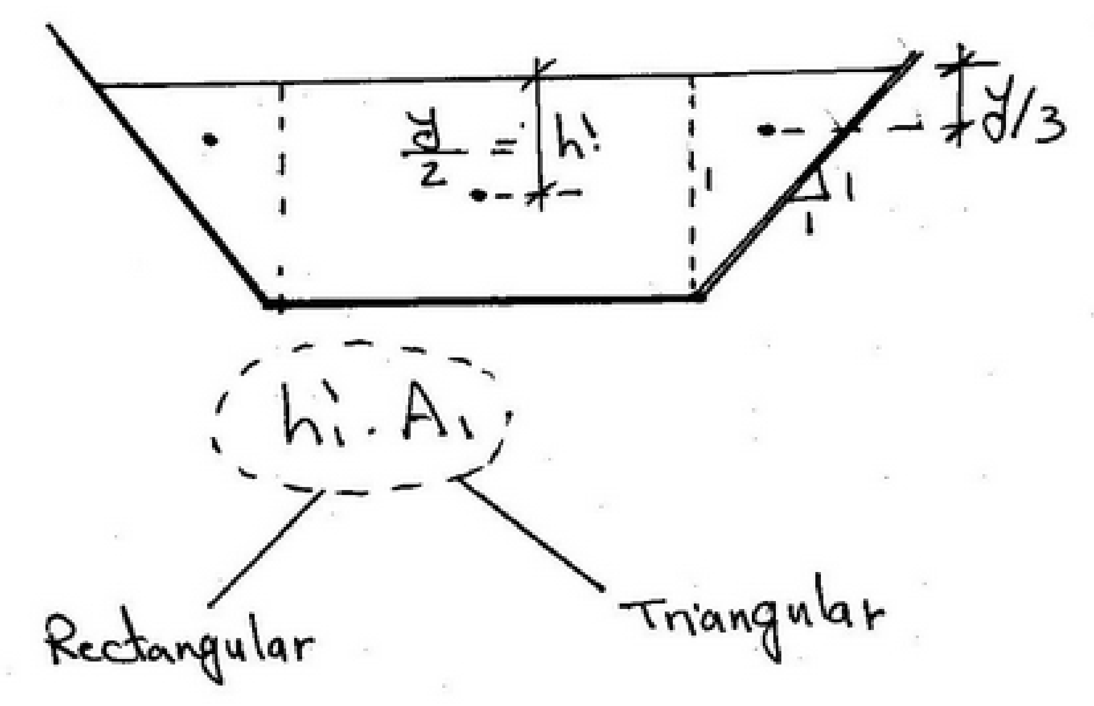
$$\because P_1 + M_1 = P_2 + M_2$$

Control volume

$$\therefore h'_1 \cdot A_1 + \frac{Q^2}{gA_1} = h'_2 \cdot A_2 + \frac{Q^2}{gA_2}$$

$$A_1 = (b + zy_1)y_1 = 17.25\,m^2$$

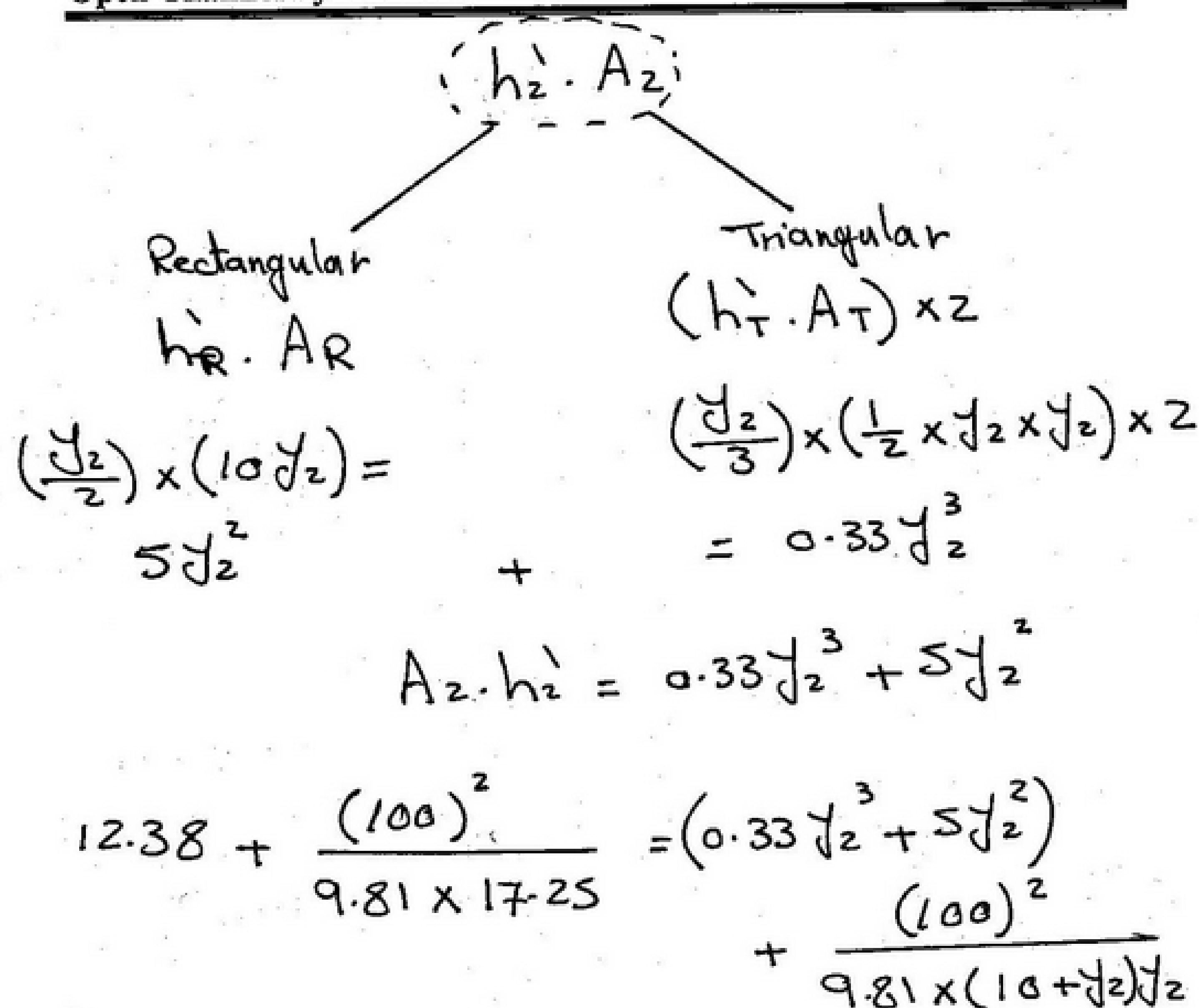
$$A_2 = (b + zy_2)y_2 = (10 + y_2)y_2$$



$h'_R \cdot A'_R$

$$\left(\frac{1.5}{2}\right) \times (10 \times 1.5) \quad + \quad \left(\frac{1.5}{3}\right) \times \left(\frac{1}{2} \times 1.5 \times 1.5\right) \times 2$$

$$- A_1 \cdot h'_1 = 12.38$$



$$h'_2 \cdot A_2$$

Rectangular: $h'_R \cdot A_R$

$$\left(\frac{y_2}{2}\right) \times (10 y_2) = 5 y_2^2$$

+

Triangular: $(h'_T \cdot A_T) \times 2$

$$\left(\frac{y_2}{3}\right) \times \left(\frac{1}{2} \times y_2 \times y_2\right) \times 2 = 0.33 y_2^3$$

$$A_2 \cdot h'_2 = 0.33 y_2^3 + 5 y_2^2$$

$$12.38 + \frac{(100)^2}{9.81 \times 17.25} = (0.33 y_2^3 + 5 y_2^2) + \frac{(100)^2}{9.81 \times (10 + y_2) y_2}$$

$$71.47 = 0.33 y_2^3 + 5 y_2^2 + \frac{1019.4}{y_2^2 + 10 y_2}$$

by trial

y_2	3.0	2.7	2.65	
R.H.S	80.05	72.67	71.66	

$$y_2 = 2.65\ m \quad \#$$

$$E = y + \frac{V^2}{2g}$$

Potential energy (y) — kinetic energy ($\frac{V^2}{2g}$)

$$\text{Losses in kinetic energy} = \frac{V_1^2}{2g} - \frac{V_2^2}{2g}$$

$$V_1 = \frac{Q}{A_1} = \frac{100}{17.25} = 5.8\ m/s$$

$$V_2 = \frac{Q}{A_2} = \frac{100}{(10 + 2.65) \times 2.65} = 2.9\ m/s$$

$$\text{Losses in k.E} = \frac{5.8^2}{2 \times 9.81} - \frac{2.9^2}{2 \times 9.81}$$

$$= 1.29\ m \quad \#$$

$$h_L = \Delta E = E_1 - E_2$$

$$E_1 = 1.5 + \frac{5.8^2}{2\times 9.81} = 3.21 m$$

$$E_2 = 2.65 + \frac{2.9^2}{2\times 9.81} = 3.10 m$$

$$\Delta E = h_L = 0.11 m$$

$$H.P = \frac{\gamma . Q . H}{75 \times \eta}$$

$$\eta = \frac{E_2}{E_1} = \frac{3.10}{3.21} \times 100 = 96.5\%$$

$$H.P = \frac{1000 \times 100 \times 0.11}{75 \times 0.965}$$

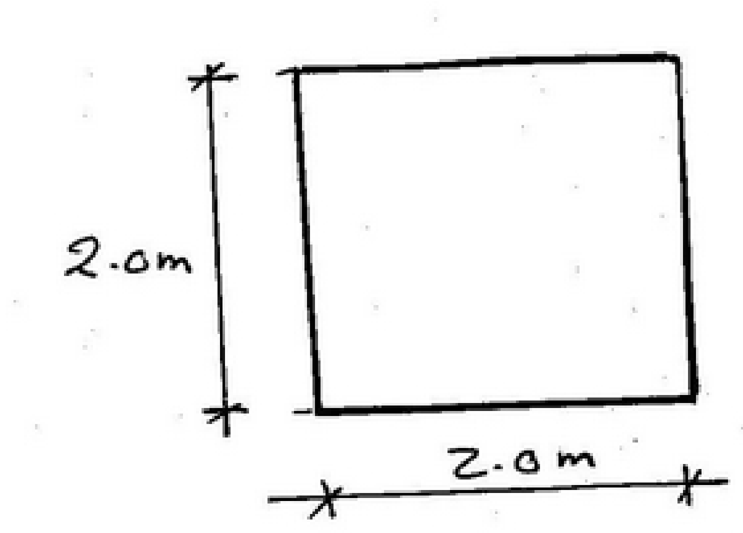
$$= 151.99 \quad H.P \ \#$$

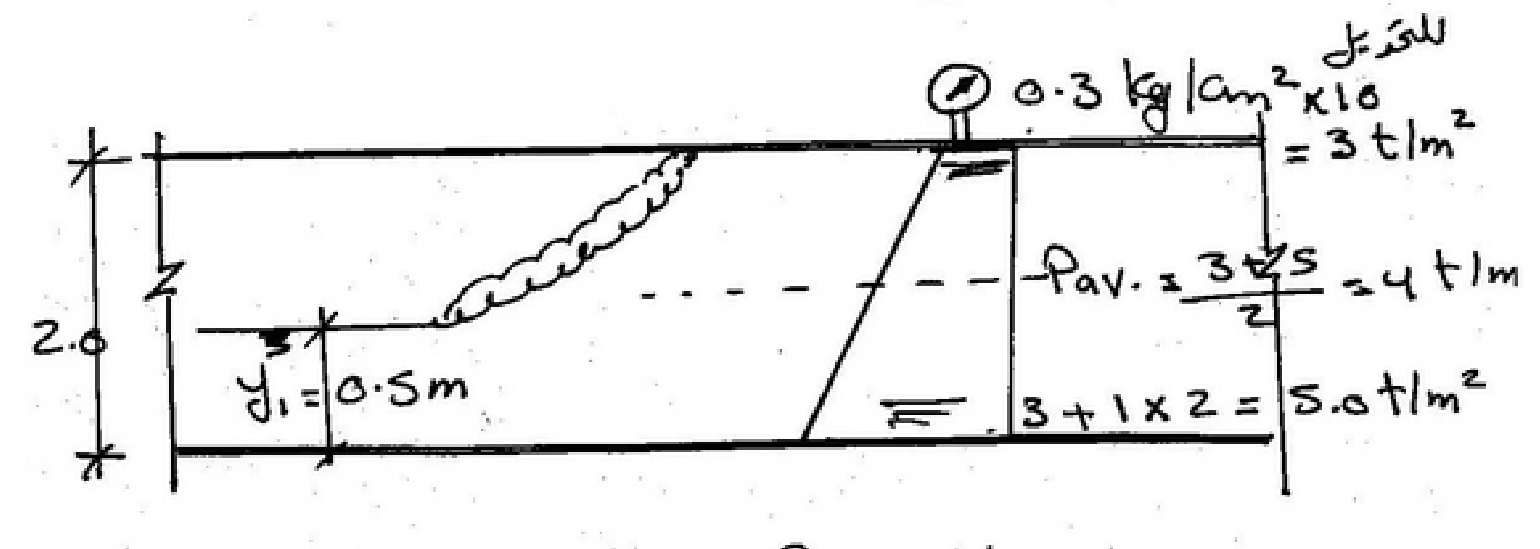
Q(4):

$y_1 = 0.50\,m$

Req.:

$Q = ??$





$$P_1 + M_1 = P_2 + M_2$$

$$\gamma \cdot h_1' \cdot A_1 + \frac{\gamma Q^2}{g A_1} = \gamma \cdot h_2' \cdot A_2 + \frac{\gamma Q^2}{g A_2}$$

$$P_{av.} \times A + \frac{\gamma Q^2}{g A_2}$$

$$1 \times \frac{0.5}{2} \times (2 \times 0.5) + \frac{1 \times Q^2}{9.81 \times (2 \times 0.5)}$$

$$= 4 \times (2 \times 2) + \frac{1 \times Q^2}{9.81 \times (2 \times 2)}$$

$$0.25 + \frac{Q^2}{9.81} = 16 + \frac{Q^2}{39.24}$$

$$Q^2 \left(\frac{1}{9.81} - \frac{1}{39.24} \right) = 16 - 0.25$$

$$Q = 14.35 \ m^3/s \ \#$$

ملحوظه

في حاله تحول السريان من تأثير الجاذبيه إلى تأثير ضغط يتم حساب

$$h' \cdot A' = P_{av.} \times A$$

Q(6) :

Stagination Point

النقطه التى عندها قيمه السرعه = صفر

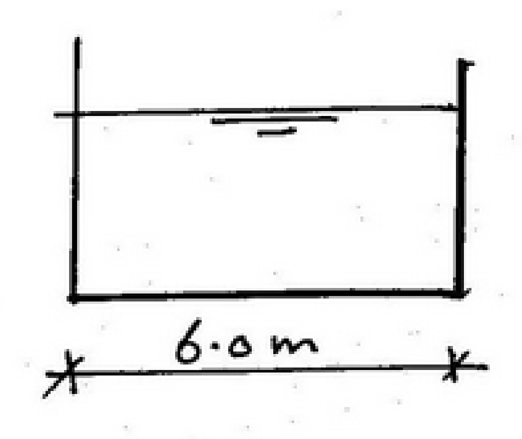
0

1

y_0

$y_1 = 1.50\,m$

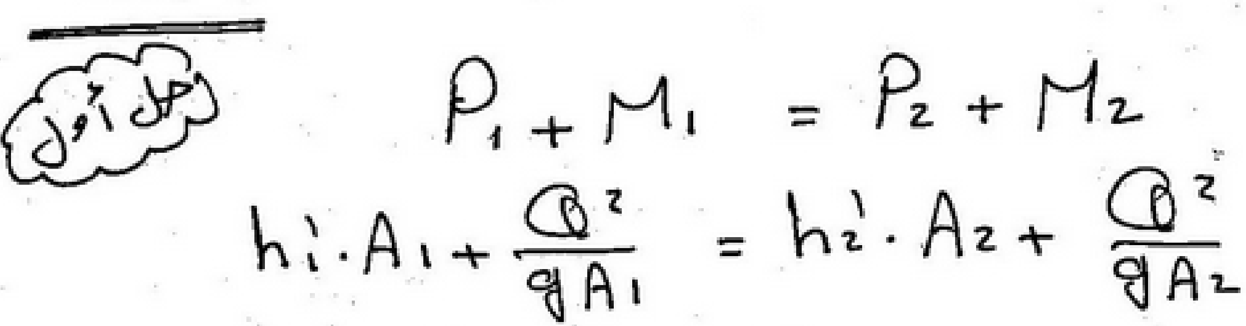
$y_2 = 3.0\,m$



Req.:

- $Q = ??$
- $y_0 = ??$

Sol.:



$$P_1 + M_1 = P_2 + M_2$$

$$h_1' \cdot A_1 + \frac{Q^2}{g A_1} = h_2' \cdot A_2 + \frac{Q^2}{g A_2}$$

- $P_1 = h'_1 \cdot A_1 = \frac{y_1}{2} \times A_1$

$= \frac{1.5}{2} \times (6 \times 1.5) = 6.75 \text{ m}$

- $M_1 = \frac{Q^2}{9.81 \times 9} = \frac{Q^2}{88.29}$

- $P_2 = h'_2 \cdot A_2 = \frac{3}{2} \times (6 \times 3) = 27$

- $M_2 = \frac{Q^2}{9.81 \times (6 \times 3)} = \frac{Q^2}{176.60}$

$$6.75 + \frac{Q^2}{88.29} = 27 + \frac{Q^2}{176.6}$$

$$Q^2 \left(\frac{1}{88.29} - \frac{1}{176.6} \right) = 27 - 6.75$$

$$Q = 59.8 \text{ m}^3/\text{s} \ \#$$

applying energy eqn between y_0, y_1

$$E_0 = E_1$$

$$E_o = y_o + \cancel{\frac{V_o^2}{2g}} = y_o$$

$V_o = 0$ (Stagination point)

$$E_1 = y_1 + \frac{V_1^2}{2g}$$

$$= 1.5 + \frac{(59.8/9)^2}{2 \times 9.81} = 3.75\,m$$

$$\therefore y_o = 3.75\ m \quad \#$$

حل آخر

For Rectangular sec.

$$y_c^3 = 0.5\, y_1 y_2 (y_1 + y_2)$$

$$y_c^3 = 0.5 \times 1.5 \times 3 \times (1.5 + 3) = 10.13$$

$$\therefore y_c = 2.16\,m$$

$$\because y_c = \sqrt[3]{q^2/g}$$

$$2.16 = \sqrt[3]{q^2/9.81}$$

$\therefore q = 9.97 \ m^3/s/m'$

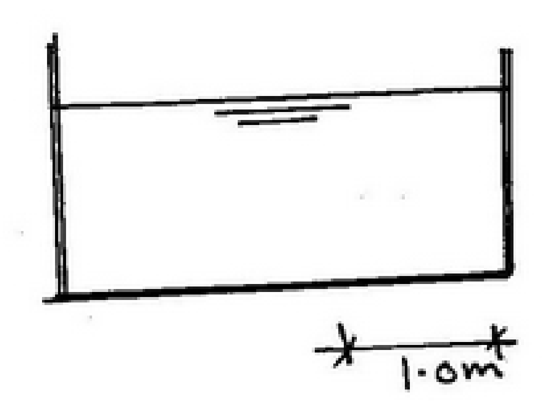
$Q = q \times b = 9.97 \times 6$

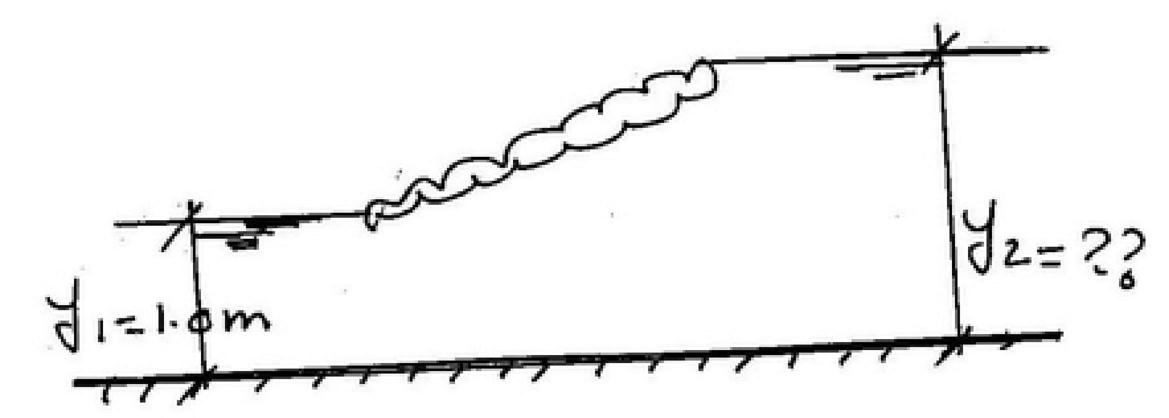
$= 59.8 \ m^3/s$ #

Q(7):

$q = 10 \ m^3/s/m'$

$y = 1.0 m$





$$\because \frac{y_2}{y_1} = 0.5\left[\sqrt{1+8F_1^2} - 1\right]$$

$$\because F_1 = \frac{V}{\sqrt{g \cdot y}}$$

$$V = q \times y \quad \text{for unit width}$$

$$V = 10 \text{ m/s}$$

$$F_1 = \frac{10}{\sqrt{9.81 \times 1}} = 3.20$$

$$\therefore \frac{y_2}{1.0} = 0.5\left[\sqrt{1 + 8 \times 3.2^2} - 1\right]$$

$$y_2 = 4.05\text{m} \quad \#$$

$$P_1 + M_1 = P_2 + M_2 + F$$

$$P_1 = h_1' \cdot A_1 = \frac{1.0}{2} * (1 \times 1.0) = 0.5$$

$$M_1 = \frac{Q^2}{g A_1} = \frac{(10)^2}{9.81 \times 1.0} = 10.20$$

$$P_2 = h_2' \cdot A_2 = \frac{3.4}{2} * (1.0 \times 3.4)$$

$$= 5.78$$

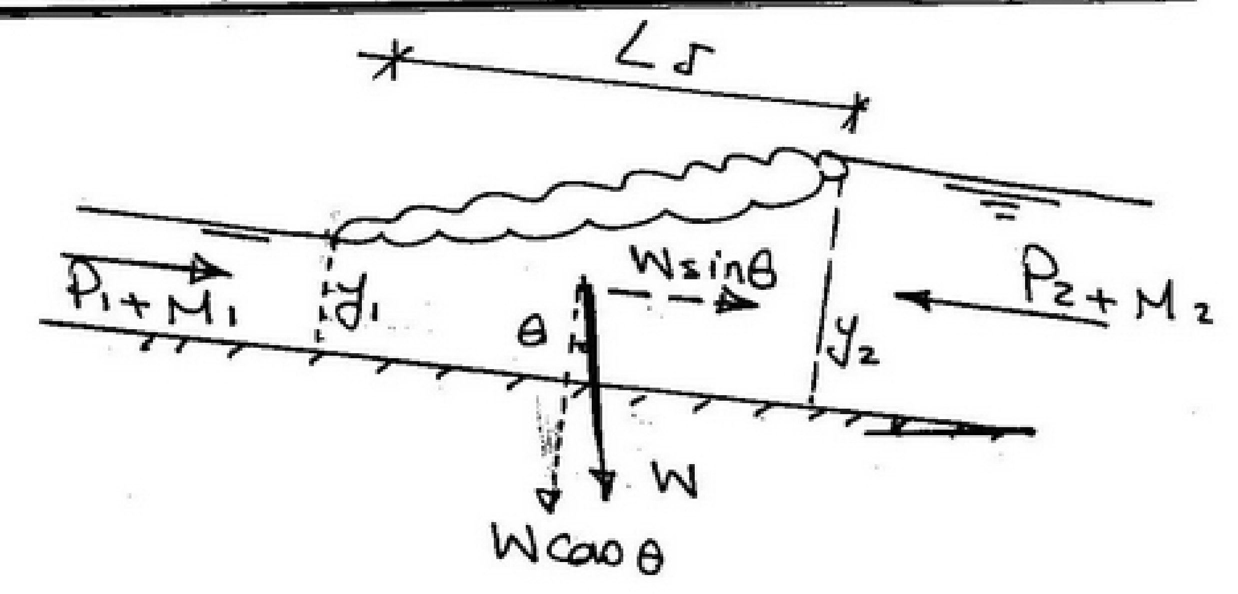
$$M_2 = \frac{Q^2}{g A_2} = \frac{(10)^2}{9.81 \times 3.4} = 3.0$$

$$0.5 + 10.2 = 5.78 + 3 + F$$

$$F = 1.92 \ t/m' \ \#$$

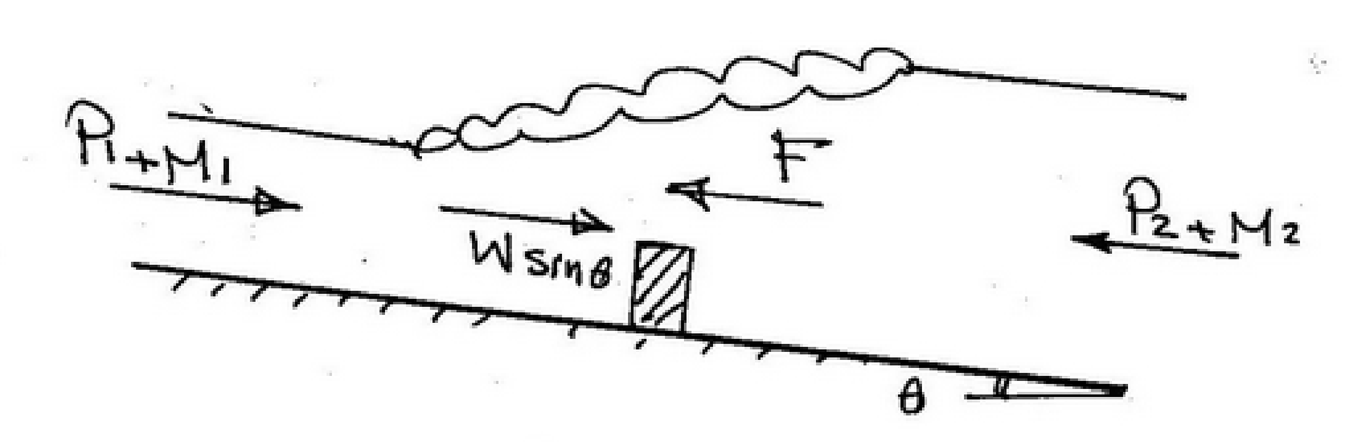
Notes

$$P_1 + M_1 = P_2 + M_2 + F_\tau$$



$$P_1 + M_1 + W\sin\theta = P_2 + M_2$$

$$W = \left[\left(\frac{y_1 + y_2}{2}\right) \times L_J\right] \times 1 \times \gamma_w$$



$$P_1 + M_1 + W\sin\theta = P_2 + M_2 + F$$